

# Electron-Beam Technologies

*A recognized leader in electron-beam and high-temperature materials technologies*

**A**t LLNL, we have more than 100,000 square feet of modern research and testing facilities devoted to the industrial deployment of production-scale electron-beam vaporization and melting systems.

Net-shape vapor forming, advanced composite materials production, and high-rate coating processes are just some of the the state-of-the-art manufacturing operations to which we are applying high-rate, electron-beam vapor deposition (EBVD) techniques.

EBVD can produce extremely high purity deposits with excellent adhesion and a surface quality that can equal that of the substrate. The microstructure and density of the deposit can also be tailored to specific applications by controlling the substrate's temperature.

## Net-shape vapor forming

Because EBVD lays down the vapor deposit atom by atom, substrate surface features are reproduced with exceptional fidelity. This has led to the current interest in net-shape vapor forming. A substrate with a negative image of the part to be formed is vapor-deposition coated. The substrate temperature is controlled to develop a preferred microstructure in the deposit. The part can also be rotated to assure a uniform coating.

The result is a highly accurate, positive replica of the substrate. At LLNL, we have produced parts roughly a centimeter thick in several hours. Applications range from rapid prototyping to producing structures that would have been expensive or difficult to fabricate using other techniques.

## APPLICATIONS

- Net-shape vapor forming
- Advanced composite materials production
- State-of-the-art, high-rate coating processes

## Advanced materials

EBVD can be used to produce advanced materials. The high purity of the deposit and the high degree of control over its microstructure makes EBVD uniquely suited for a number of important applications. The relatively low energy of the

vapor atoms makes it possible to coat delicate substrates without overheating or damaging them. The applications range from producing metal-matrix composite materials to depositing high-temperature superconductors. A major technical challenge in these processes is to precisely control the vaporized alloy's composition.

At LLNL, we are applying advanced sensor and intelligent process-control technologies to produce advanced materials. We have developed vapor-composition sensors that are based on laser-absorption spectroscopy, use relatively low-cost diode lasers, and are suitable for a production environment. LLNL has also developed a melt-viewing video system that can directly view high-rate vaporizer operations for hundreds of hours without fogging.

Model-based control systems, when combined with these sensors, have been used at LLNL to control vaporizer operations in runs lasting more than 200 hours and vaporizing several tons of material.

## Unrivaled capabilities

The Mars facility incorporates a modular several-hundred kilowatt electron-beam vaporization system. Its modular nature permits the parallel development of a number of systems while maximizing the facility's availability. Mars is fully qualified under current environmental, safety, and health guidelines to process both pyrophoric and radioactive materials.

The Electron-beam Testing Facility (ETF) also has a several-hundred kilowatt, high-rate vaporization, electron-beam system and can do concept demonstration testing for many vapor-deposition and process-control applications.

A commercial, 14-kilowatt, electron-beam source complements the two larger facilities. This smaller system can be used for diagnostics development and for developing prototypes of various thin-film deposition processes.

The diagnostic-laser laboratories at LLNL provide unrivaled capabilities for the monitoring and control of vaporization processes.

They are equipped with ion-laser-pumped ring dye lasers, Ti:sapphire lasers, and tunable-diode lasers. All of our vaporizer facilities have diagnostic laser capability.

Our specific areas of expertise include: high-efficiency-vaporizer design/operation; on-line monitoring and control; thermal design and control; vapor diagnostics and plume characterization; and process modeling and simulation.

**Availability:** LLNL is seeking industrial partners interested in developing EBVD processes and technology for manufacturing applications.

**Contact**

*Thomas A. Shepp*

*Phone: (510) 422-6192*

*Fax: (510) 422-6724*

*E-mail: [shepp1@llnl.gov](mailto:shepp1@llnl.gov)*

*Mail code: L-470*